

# 12.3 Magnetic Fields of Current-Carrying Wires and the Biot-Savart Law

Name: \_\_\_\_\_ Class: \_\_\_\_\_ Date: \_\_\_\_\_

Total: 9 marks

## Objective

Build the skills to answer exam questions on **magnetic fields of current-carrying wires and the Biot-Savart law**.

You must be able to:

- state the **Biot-Savart law** 毕奥-萨伐尔定律,  $d\vec{B} = \frac{\mu_0 I d\vec{l} \times \hat{r}}{4\pi r^2}$
- calculate the field of a **long straight wire**,  $B = \frac{\mu_0 I}{2\pi r}$
- find the field at the **centre of a circular loop**,  $B = \frac{\mu_0 I}{2R}$
- use the **right-hand rule** for field direction

## 1 Worked examples

Study these first. Each one shows the method for a question type used later.

### ■ The Biot-Savart law

$d\vec{B} = \frac{\mu_0 I d\vec{l} \times \hat{r}}{4\pi r^2}$  gives the field of a small current element; integrate over the wire for the total field ( $\mu_0 = 4\pi \times 10^{-7}$ ).

### ■ Standard results

- Long straight wire:  $B = \frac{\mu_0 I}{2\pi r}$ .
- Centre of a circular loop of radius  $R$ :  $B = \frac{\mu_0 I}{2R}$ .

### ■ Direction

Curl the right hand around the wire with the thumb along the current; the fingers give the field direction.

## 2 Practice

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**2.1** Find the field 0.050 m from a long wire carrying 8.0 A ( $\mu_0 = 4\pi \times 10^{-7}$ ). [2]

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**2.2** State the rule used to find the direction of the field around a straight wire. [1]

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**2.3** Write the field at the centre of a circular loop of radius  $R$  carrying current  $I$ . [1]

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### 3 Exam-style questions

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**3.1** The magnetic field of a long straight wire is [1]

- **A**  $\frac{\mu_0 I}{2\pi r}$
  - **B**  $\frac{\mu_0 I}{2R}$
  - **C**  $\mu_0 nI$
  - **D**  $BIL$
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**3.2** The Biot-Savart law gives the field of a [1]

- **A** current element
  - **B** point charge
  - **C** capacitor
  - **D** resistor
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**3.3** A circular loop of radius 0.10 m carries 5.0 A ( $\mu_0 = 4\pi \times 10^{-7}$ ).

(a) Find the magnetic field at its centre. [2]

(b) State how the field changes if the current is doubled. [1]

## 4 Go further

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- work through the **12.3 Magnetic Fields of Current-Carrying Wires and the Biot-Savart Law** lesson on the **Learn** page;
- read the **Magnetic Fields** section of the AP Physics C: E&M handout on the **Know** page.

## Solutions

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**2.1**  $B = \frac{\mu_0 I}{2\pi r} = \frac{(4\pi \times 10^{-7})(8.0)}{2\pi(0.050)} = 3.2 \times 10^{-5} \text{ T}.$

**2.2** the right-hand rule (grip rule).

**2.3**  $B = \frac{\mu_0 I}{2R}.$

**3.1 A.**

**3.2 A.**

**3.3** (a)  $B = \frac{\mu_0 I}{2R} = \frac{(4\pi \times 10^{-7})(5.0)}{2(0.10)} = 3.1 \times 10^{-5} \text{ T}.$  (b) it doubles ( $B \propto I$ ).